

## Explaining Equilibrium

1) For each of the following changes applied to this system:

- (i) State if the amount of **chlorine gas,  $\text{Cl}_2(g)$** , would increase or decrease.
- (ii) Justify your answers using equilibrium principles.

**$\text{PCl}_3(g)$  is removed.**

Reason:

**The pressure is decreased.**

Reason:

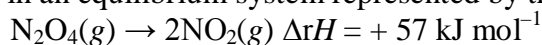
2) When the temperature of the equilibrium system is increased from  $200^\circ\text{C}$  to  $350^\circ\text{C}$  (at constant pressure), the value of  $K_c$  increases, as shown in the table

Temperature/ $^\circ\text{C}$	Value of $K_c$
200	$8.00 \times 10^{-3}$
350	0.612

Use this information to determine whether the decomposition of  $\text{PCl}_5$  is endothermic or exothermic.

Justify your reasoning using equilibrium principles.

3) Two oxides of nitrogen exist in an equilibrium system represented by the following equation.



$\text{N}_2\text{O}_4$  is a colourless gas and  $\text{NO}_2$  is a brown gas.

For each of the following changes applied to this equilibrium system in (i) and (ii) below:

- describe the expected observation
- use equilibrium principles to explain this observation.

(i) The reaction mixture is cooled.

(ii) The pressure is decreased.

4) The following reaction can be used to produce gaseous methanol,  $\text{CH}_3\text{OH}$ , from carbon monoxide and hydrogen.

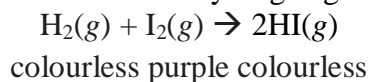


Below are three possible factors that could be changed to alter the amount of methanol produced in this reaction.

Factor	Possible change
Temperature	increased or decreased
Catalyst	addition of a copper oxide catalyst
Pressure	increased or decreased

Discuss the changes which could be made to **increase** the amount of **methanol** produced. Your answer should relate each of the factors in the table above to equilibrium principles.

5) The following equilibrium system is formed when hydrogen gas is mixed with iodine gas.



The reaction has a negative value for  $\Delta_r H$ .

For each of the following changes applied to this system:

(i) describe the expected observation

(ii) use equilibrium principles to discuss the reason for this observation.

**HI(g) is added.**

Expected observation:

Reason:

**The reaction mixture is cooled.**

Expected observation:

Reason:

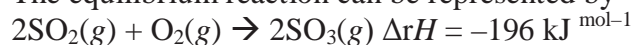
**The pressure is increased.**

Expected observation:

Reason:

6) One step in the production of sulfuric acid involves forming sulfur trioxide from sulfur dioxide.

The equilibrium reaction can be represented by



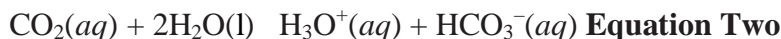
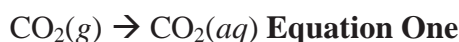
(a) (i) Explain why a low temperature favours the formation of  $\text{SO}_3(\text{g})$ .

(ii) The temperature that is actually used is approximately  $450^\circ\text{C}$ . However, this is not considered to be a low temperature. Discuss why this temperature is used.

(b) (i) Describe another way of increasing the amount of  $\text{SO}_3(\text{g})$  present at equilibrium without adding any more reactants.

(ii) Explain why this will increase the amount of  $\text{SO}_3(\text{g})$  present at equilibrium.

7) Carbon dioxide is added to drinks to make them **fizzy**. The following equilibria are involved:



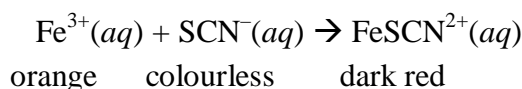
The drink is **fizzy** when there is dissolved carbon dioxide,  $\text{CO}_2(\text{aq})$ . The drink stops being fizzy when the carbon dioxide escapes from the drink as a gas.

Using equilibrium principles, discuss the changes that occur as a bottle containing fizzy drink is opened.

Your answer must include reference to:

- equilibrium shift in **Equation One** and **Equation Two**
- changes in the fizziness of the drink
- any change in pH.

8) The following equilibrium system is formed when potassium thiocyanate solution is added to a solution of iron(III) nitrate.

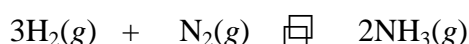


The reaction has a positive value for  $\Delta_r H$ .

For each of the following changes applied to this system:

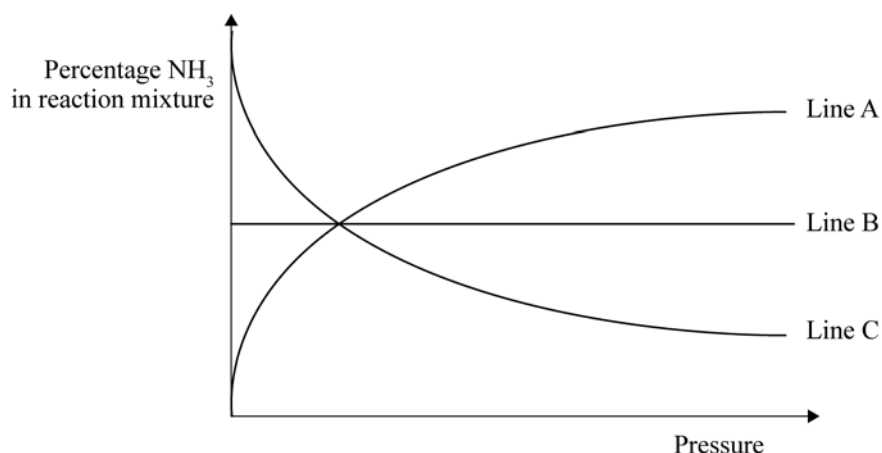
- describe the expected observation
  - use equilibrium principles to discuss the reason for this observation.
- (a) The reaction mixture is cooled.
- -
- (b) Solid sodium fluoride is added to the reaction mixture. The fluoride ions react with  $\text{Fe}^{3+}$  ions.
- -
- (c) Solid iron(III) chloride is added to the reaction mixture.
- -

9) An equilibrium system is shown below.



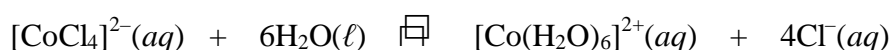
- (a) Write the equilibrium constant expression for this reaction.

The pressure of the system is increased, while maintaining a constant temperature. The percentage of  $\text{NH}_3$  in the reaction mixture is recorded and graphed.



- (b) On the above graph, identify the line that shows the correct relationship between the percentage of  $\text{NH}_3$  in the reaction mixture, and increasing pressure. Explain your answer by applying knowledge of equilibrium principles.

10) An equilibrium system involving different species of cobalt(II) is shown in the equation below.



$[\text{CoCl}_4]^{2-}(\text{aq})$  is blue and  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$  is pink.

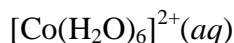
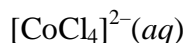
At room temperature ( $25^\circ\text{C}$ ) the equilibrium mixture is pink.

- (a) Describe the expected observation when solid sodium chloride ( $\text{NaCl}$ ) is added to the equilibrium mixture. Explain your answer.

Observation:

Explanation:

- (b) The enthalpy change ( $\Delta_r H$ ) for this reaction as written above, has a negative value. **Circle** the ion that would be present in the higher concentration when the equilibrium mixture is heated.



Explain your answer.

11) The following reaction is exothermic:



Both  $\text{N}_2\text{O}_5$  and  $\text{O}_2$  are colourless gases and  $\text{NO}_2$  is a brown gas.

A mixture of these gases exists at equilibrium and is observed as a brown colour.

- (a) Write the equilibrium constant expression for the reaction.
- (b) For each of the following changes applied to the equilibrium system, describe the expected observation and explain why this occurs.

- (i) The mixture of gases is heated (at constant pressure).

Expected observation:

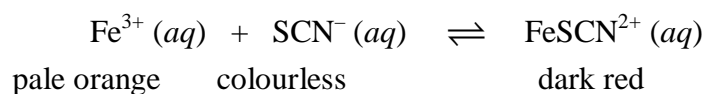
Explanation:

- (ii) The pressure is increased, by decreasing the volume of the container.

Expected observation:

Explanation:

- 12) (a) The following equilibrium system is established when thiocyanate ions ( $\text{SCN}^-$ ) are added to iron (III) ions ( $\text{Fe}^{3+}$ ). The resulting aqueous solution is a dark red colour. The equation representing the equilibrium system and the colours of each species involved are given below.



- (i) Complete the equilibrium constant expression for the above reaction.
- (ii) When iron (III) ions ( $\text{Fe}^{3+}$ ) are removed from the equilibrium mixture (by adding sodium fluoride), a colour change is observed. Describe the colour change you would expect to see and explain why it occurs.

- (b) Ammonia is produced industrially according to the Haber Process as shown below:



- (i) Complete the equilibrium constant expression for the above reaction.
- (ii) The pressure of the system at equilibrium is increased (by decreasing the total volume of the system). Describe the effect of this change on the amount of  $\text{NH}_3$  in the system. Explain your answer.
- (iii) The percentage of  $\text{NH}_3$  present in equilibrium mixtures at different temperatures and at constant pressure is shown in the table below.

Temperature (°C)	Percentage NH <sub>3</sub> present in equilibrium mixture
200	63.6
300	27.4
400	8.7
500	2.9

Justify whether the reaction in which NH<sub>3</sub> is formed, is endothermic or exothermic